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Feasibility of Beauty Baryon Polarization Measurement in Λ^0 J/ψ decay channel by ATLAS-LHC

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Abstract

The possibility of beauty baryon polarization measurement by cascade decay angular distribution analysis in the channel Λ^0 J/ψ $\to p\pi^- l^+ l^-$ is demonstrated. The error analysis shows that in the proposed LHC experiment ATLAS at the luminosity $10^4 pb^{-1}$ the polarization can be measured with the statistical precision better than $\delta = 0.010$ for Λ_b^0 and $\delta = 0.17$ for Ξ_b^0 .

Introduction

The study of polarization effects in multiparticle production provides an important information on spin-dependence of the quark confinement. Thus substantial polarization of the hyperons produced in nucleon fragmentation processes [1, 2] as well as the data on the hadron polarization asymmetry were qualitatively described by recombination quark models taking into account the leading effect due to the valence hadron constituents [3−6]. Although these models correctly predict practically zero polarization of $\overline{p}$,$\overline{\Lambda}$ and Ω^-, they fail to explain the large polarization of antihyperons $\overline{\Xi^+}$ and $\overline{\Sigma^-}$ recently discovered in Fermilab [7, 8].

The problem of quark polarization effects could be clarified in polarization measurements involving heavy quarks. In particular, an information about the quark mass dependence of these effects could be obtained [4, 9]. The polarization is expected to be proportional to the quark mass if it arises due to scattering on a colour charge [10 − 12]. The opposite dependence takes place if the quark becomes polarized due to the interaction with an "external" confining field, e.g., due to the effect of spontaneous radiation polarization [13]. The decrease of the polarization with increasing quark mass is expected also in the model of ref. [14].

In QCD the polarization might be expected to vanish with the quark mass due to vector character of the quark-gluon coupling [10]. It was shown however in Ref.[15] that the quark mass should be effectively replaced by the hadron mass M so that even the polarization of ordinary hadrons can be large. The polarization is predicted to be independent of energy and to vanish in the limit of both low and high hadron transverse momentum p_t . The maximal polarization $P_{max}(x_F)$ is reached at $p_t \approx M$ and depends on the Feynman variable x_F. Its magnitude (and in particular its mass dependence) is determined by two quark-gluon correlators which are not predicted by perturbative QCD.

The polarization of charm baryons in hadronic reactions is still unmeasured due to the lack of sufficient statistics. Only some indications on a nonzero polarization were reported [16, 17]. For beauty physics the future experiments on LHC or HERA give an opportunity to obtain large statistical samples of beauty baryon (Λ_b^0 , Ξ_b^0) decays into $\Lambda^0 \ J/\psi \ \to p\pi^-l^+l^-$, which is favorable mode to detect experimentally. Dedicated triggers for CP-violation effects in b-decays, like the high-p_t one-muon trigger (LHC) [18] or the J/ψ trigger (HERA) [19] are selective also for this channel.

Below we consider the possibility of polarization measurement of beauty baryons Λ_b^0 and Ξ_b^0 with the help of cascade decay angular distributions in the channel Λ_b^0 (Ξ_b^0) $\to$ $\Lambda^0 \ J/\psi \ \to p\pi^-l^+l^-$.

Polarization measurement method and an estimation of the statistical error.

In the case of parity nonconserving beauty baryon (B_b) decay the polarization causes the asymmetry of the distribution of the cosine of the angel θ between the beauty baryon decay and production analyzers:

$$w(\cos\theta) = \frac{1}{2}(1 + \alpha_b P_b \cos\theta), \tag{1}$$

where P_b is a projection of the polarization vector on the production analyzer and α_b is a decay asymmetry parameter. As the polarization vector is perpendicular to B_b production plane (due to parity conservation in the production process), the production analyzer should be directed parallel to the normal to this plane: $\vec{n} = \frac{\vec{p}_{inc}\times\vec{p}_{B_b}}{|\vec{p}_{inc}\times\vec{p}_{B_b}|}$, where $\vec{p}_{inc}$ and $\vec{p}_{B_b}$ are momenta of incident particle and B_b in c.m. system.

The asymmetry parameter α_b characterizes parity nonconservation in a weak decay of B_b and depends on the choice of the decay analyzer. In the two-body decay $B_b \to \Lambda^0\ J/\psi$ it is natural to choose this analyzer oriented in the direction of Λ^0 momentum $\vec{p}_{\Lambda^0}$ in the B_b rest system. The considered decay can be described by 4 helicity amplitudes $A(\lambda_1, \lambda_2)$ normalized to unity: $a_+ = A(1/2, 0)$,$a_- = A(-1/2, 0)$, $b_+ = A(-1/2, 1)$ and $b_- = A(1/2, -1)$,

$$|a_+|^2 + |a_-|^2 + |b_+|^2 + |b_-|^2 = 1. \tag{2}$$

The difference of Λ^0 and J/ψ helicities λ_1 - λ_2 is just a projection of B_b spin onto the decay analyzer. The decay asymmetry parameter α_b is expressed through these amplitudes in the form

$$\alpha_b = |a_+|^2 - |a_-|^2 + |b_+|^2 - |b_-|^2. \tag{3}$$

If P-parity in B_b decay were conserved, then $|a_+|^2 = |a_-|^2$, $|b_+|^2 = |b_-|^2$ so that α_b would be 0. In the case of known and sufficiently nonzero value of α_b the beauty baryon polarization could be simply measured with the help of angular distribution (1) (see, e.g., [20]). Due to lack of experimental information and rather uncertain theoretical estimates of α_b for the decay $\Lambda_b^0 \to \Lambda^0\ J/\psi$ [21] both the polarization and α_b (or the decay amplitudes) should be determined simultaneously. This can be achieved with the

help of information on Λ^0 and J/ψ decays. Though it complicates the analysis, it should be stressed that the measurement of the beauty baryon decay amplitudes could give valuable constrains on various theoretical models. Generally, such a measurement can be done provided that at least one of the secondary decays is asymmetric and its decay asymmetry parameter is known [9]. In our case it is the decay $\Lambda^0 \to p\pi^-$ with the asymmetry parameter α_Λ=0.642.

The angular distribution in the cascade decay $B_b \to \Lambda^0\ J/\psi \to p\pi^- l^+ l^-$ follows directly from Eq. (6) of [9], taking into account that the only nonzero multipole parameters in the decay $J/\psi \to l^+ l^-$ are T_{00}=1 and $T_{20}=\frac{1}{\sqrt{10}}$. It can be written in the form

$$w(\Omega, \Omega_1, \Omega_2) = \frac{1}{(4\pi)^3} \sum_{i=0}^{i=19} f_{1i} f_{2i}(P_b, \alpha_\Lambda) F_i(\theta, \theta_1, \theta_2, \phi_1, \phi_2), \quad (4)$$

where f_{1i} are bilinear combinations of the decay amplitudes a_+, a_-, b_+, b_-, $f_{2i}(P_b, \alpha_\Lambda)$ stands for $P_b\alpha_\Lambda$, P_b, α_Λ or 1 and F_i are orthogonal angular functions (Table1). Ω=(θ,ϕ) are the polar and the azimuthal angles of the Λ^0 momentum $\vec{p}_{\Lambda^0}$ in the B_b rest frame with z-axis parallel to the production normal $\vec{n}$ (the choice of x and y axes is not important since parity conservation in the production process guarantees independence of the azimuthal angle ϕ), Ω_1=(θ_1,ϕ_1) are the angles of proton momentum in the Λ^0 rest frame with axes defined as $z_1 \uparrow\uparrow \vec{p}_{\Lambda^0}$, $y_1 \uparrow\uparrow \vec{n} \times \vec{p}_{\Lambda^0}$, Ω_2=(θ_2,ϕ_2) are the angles of the momentum of one of the decay leptons in the J/ψ rest frame with axes defined as $z_2 \uparrow\uparrow \vec{p}_{J/\psi}$, $y_2 \uparrow\uparrow \vec{n} \times \vec{p}_{J/\psi}$ ($\vec{p}_{J/\psi}$=$-\vec{p}_{\Lambda^0}$ is J/ψ momentum in the B_b rest frame).

This distribution depends on 7 unknown independent parameters. One of them is the polarization P_b and six others determine the four complex amplitudes

$$a_+ = |a_+|e^{i\alpha_+}, a_- = |a_-|e^{i\alpha_-}, b_+ = |b_+|e^{i\beta_+}, b_- = |b_-|e^{i\beta_-}. \quad (5)$$

Taking into account the normalization condition and arbitrariness of the common phase, these parameters can be chosen as

$$\alpha_b, r_0 = |a_+|^2 + |a_-|^2, |a_+|^2 - |a_-|^2, \alpha_+, \alpha_-, \chi = \alpha_+ + \alpha_- - \beta_+ - \beta_-. \quad (6)$$

The parameters can be determined from the measured decay angles by a 5-dimensional likelihood fit or by the moment method: the angular distribution of the form (4) allows one to introduce 19 moments $< F_i >\sim f_{1i}.f_{2i}$ and determine the parameters from their measured values by weighted least-squares method. For the polarization measurement the

formula (4) integrated over the azimuthal angles ϕ_1, ϕ_2 would be in principle sufficient [9]. In this case the number of free parameters is reduced to 4 (the phases don't enter) and only a 3-dimensional fit is required. We will see, however, that the information on these angles may substantially increase the precision of the P_b determination.

To simplify the error analysis, we follow ref. [9] and consider here only the most unfavourable situation, when the parameters P_b^2,$|a_+|^2-|a_-|^2$ and $|b_+|^2-|b_-|^2$ are much smaller than α_Λ^2. In this case the moments $< F_i >$ can be considered to be independent, having the diagonal error matrix

$$W = \frac{1}{N} diag(\frac{1}{3}, \frac{1}{3}, \frac{1}{9}, \frac{1}{5}, \frac{1}{15}, \frac{1}{15}, \frac{1}{45}, \frac{16}{135}, \frac{16}{135}, \frac{16}{135}, \frac{16}{135}, \frac{2}{135}, \frac{2}{135}, \frac{2}{135}, \frac{2}{135}, \frac{2}{45}, \frac{2}{45}, \frac{2}{45}, \frac{2}{45}). \qquad (7)$$

Here N is a number of B_b events (assuming that the background can be neglected, see next section). The error matrix V of the vector $\vec{a}$ of the parameters a_j,j=1,..7 defined in (6) is

$$V(\vec{a}) = (A^T W^{-1} A)^{-1}, \qquad (8)$$

where the elements of the matrix A are $A_{ij} = \frac{d(f_{1i}.f_{2i})}{da_j}$. In the considered situation the error on the polarization P_b is

$$\delta \equiv \sqrt{V_{11}} = \frac{\delta_0}{\sqrt{N}}, \qquad (9)$$

$$\delta_0 = \frac{1}{\sqrt{\alpha_\Lambda^2 \cdot [\frac{(2r_0-1)^2}{9} + \frac{(r_0+1)^2}{180} + \frac{4r_0^2}{15} + \frac{(1-r_0)^2}{15} + \frac{(1-r_0)(1+\cosh\chi)}{15}] + \frac{r_0(1-r_0)(1-\cosh\chi)}{10}}}. \qquad (10)$$

Here δ_0 depends only on the relative contribution r_0 of the decay amplitudes with helicity $\lambda_2 = 0$ and on the relative phase χ (Figs. 1a,b). The maximal error on P_b is $\delta_{\max} = \frac{4.7}{\sqrt{N}}$ and it corresponds to the case when $r_0 = \frac{1}{3}$ and the phase $\chi = 0$. The minimal error in the considered most unfavorable situation is $\delta_{\min} = \frac{2.5}{\sqrt{N}}$. It is obtained in the case when only $\lambda_2 = 0$ helicity amplitudes contribute ($r_0 = 1$), independently of their phases. If the information on the azimuthal angles would be neglected then $\delta_{\max} = \frac{14.0}{\sqrt{N}}$ and $\delta_{\min} = \frac{4.3}{\sqrt{N}}$.

Estimates of indirect Λ_b^0 and Ξ_b^0 production, background processes and possible statistics at ATLAS-LHC

The beauty baryons Λ_b^0 and Ξ_b^0 are produced directly or through the decays of heavier states. According to the PYTHIA tables we consider here the strong decays $\Sigma_b \to \Lambda_b^0\ \pi$

, $\Sigma_b^* \to \Lambda_b^0\ \pi$ and the electromagnetic decays $\Xi_b^{0'} \to \Xi_b^0\ \gamma$ or $\Xi_b^{0*} \to \Xi_b^0\ \gamma$.The observable polarization P_{obs} depends on the polarizations P_{B_b} of direct beauty baryons and their production fractions b_{B_b} (i.e. probabilities of the b-quark to hadronize to certain baryons B_b). In considered decays the beauty baryon Λ_b^0 or Ξ_b^0 retains $\frac{-1}{3}(\frac{1}{3})$ of the polarization of a parent with spin $\frac{1}{2}^+(\frac{3}{2}^+)$ (see Appendix). For P_{obs} we get:

$$P_{obs} = \frac{b_{\Lambda_b^0} P_{\Lambda_b^0} + \sum_i (\frac{-1}{3} b_{\Sigma_{bi}} P_{\Sigma_{bi}} + \frac{1}{3} b_{\Sigma_{bi}^*} P_{\Sigma_{bi}^*})}{b_{\Lambda_b^0} + \sum_i (b_{\Sigma_{bi}} + b_{\Sigma_{bi}^*})}, \tag{11}$$

for Λ_b^0 and for Ξ_b^0 :

$$P_{obs} = \frac{b_{\Xi_b^0} P_{\Xi_b^0} + \frac{-1}{3} b_{\Xi_b^{0'}} P_{\Xi_b^{0'}} + \frac{1}{3} b_{\Xi_b^{0*}} P_{\Xi_b^{0*}}}{b_{\Xi_b^0} + b_{\Xi_b^{0'}} + b_{\Xi_b^{0*}}}. \tag{12}$$

The summation goes over positive, negative and neutral Σ_b and Σ_b^*. Assuming the polarization of the heavier states to be similar in magnitude to that of directly produced Λ_b^0 or Ξ_b^0 ($P_{\Lambda_b^0}$ or $P_{\Xi_b^0}$) we may expect the observed polarization in an interval of $(0.34-0.67)P_{\Lambda_b^0}$ for Λ_b^0 and $(0.69-0.84)P_{\Xi_b^0}$ for Ξ_b^0 .

The polarization can be measured for Λ_b^0 and Ξ_b^0 baryons and for their antiparticles. Λ_b^0 (Ξ_b^0) are unambigously distinquishable from their antiparticles by effective mass of $p\pi^-$ system from $\Lambda^0\ \to p\pi^-$ decay. The wrong assignment of antiproton and pion masses gives the kinematical reflection of $\overline{\Lambda^0}$ starting at 1.5 GeV which is far from Λ^0 mass comparing to the mass resolution of Λ^0 produced in the decays of Λ_b^0 or Ξ_b^0 .

Λ_b^0 and Ξ_b^0 can be distinguished from each other by the effective mass of the $p\pi^- l^+ l^-$ system. The mass difference of Λ_b^0 and Ξ_b^0 is $220 MeV$. The mass resolution in this region (taking into account the table mass values for Λ^0 and J/ψ candidates) is $\sigma_{\Lambda^0 J/\psi} \approx 26 MeV$ for $\Lambda^0\ J/\psi\ \to p\pi^-\mu^+\mu^-$
channel. Thus even the background from Λ_b^0 in the region of masses $m_{\Xi_b^0} \pm 3\sigma_{\Lambda^0 J/\psi}$ is negligible.

There are several other sources of background to $\Lambda^0\ J/\psi$ decays of Λ_b^0 and Ξ_b^0 . The dominant background comes from J/ψ from b-hadron decays and Λ^0 produced in fragmentation or in the decay of the same b-hadron. After the cutting off the low transverse momenta (less than $0.5 GeV$) of p and π from Λ^0 decay this background can be reduced to $\approx 1.5\%$ in a region of $m_{\Lambda_b^0} \pm 3\sigma_{\Lambda_b^0 J/\psi}$(Figs. 2a,b). The remaining background comes mainly from two processes: $\Xi_b^0\ \to \Xi^0 J/\psi$, $\Xi^0 \to \Lambda^0\ \pi^0$ and $\Xi_b^- \to \Xi^- J/\psi$, $\Xi^- \to \Lambda^0\ \pi^-$. For Ξ_b^0 this background (Fig.3a) is more important ($\approx 20\%$). The reason is that the decay

Ξ_b^0 is governed by $b \to dc\bar{c}$ process which is Cabbibo suppressed by a factor $\sin(\theta_c)^2 = 0.22^2$ compared to the decays $\Xi_b^0 \to \Xi^0 J/\psi$, $\Xi_b^- \to \Xi^- J/\psi$ and also $\Lambda_b^0 \to \Lambda^0\ J/\psi$, which are governed by $b \to sc\bar{c}$. However Λ^0 from $\Xi_b^0 \to \Xi^0 J/\psi$ or $\Xi_b^- \to \Xi^- J/\psi$ is produced in a weak hyperon decay, so this background can be efficiently reduced by the cut on the minimal distance d between J/ψ and Λ^0 . A conservative cut $d < 1.5mm$ reduces this background by a factor ≈ 0.05 (Fig. 3b).

The background from $B_d^0 \to J/\psi K^0$ when one of π mesons is considered as a proton is negligible after the effective mass cuts on $(p\pi)$ and $(p\pi J/\psi)$ systems.

Background from fake $J/\psi's$, as it has been shown in [18], can be reduced to a low level by cuts on the distance between the primary vertex and the production point of the J/ψ candidate and the distance of closest approach between the two particles from the decay. These cuts also suppress the background from real $J/\psi's$ comming directly from hadronization.

The number of produced Λ_b^0 and Ξ_b^0 is calculated for the cross section of pp $\to$ b $\overline{\text{b}}$ X equal to $500\mu b$. The production fraction $b_{\Lambda_b^0}$ of $b \to \Lambda_b$ multiplied by branching ratio $br_{\Lambda_b^0}$ of $\Lambda_b^0 \to \Lambda^0\ J/\psi$ decay was measured in two experiments: UA1 [22] gives the value $b_{\Lambda_b^0}.br_{\Lambda_b^0} = 1.8 \pm 0.6\ 10^{-3}$ while CDF [23] put only an upper limit on this value of $0.5\ 10^{-3}$ which we'll use as a conservative estimate in statistics and error calculations. From PYTHIA generator $b_{\Lambda_b^0} = 0.08$ including also Λ_b^0 produced in strong Σ_b decays. If we neglect possible changes of the production fractions with the energy the value of $br_{\Lambda_b^0} = 2.2\ 10^{-2}$ can be derived from UA1 result or the upper limit value on $br_{\Lambda_b^0}$ of $0.6\ 10^{-2}$ from CDF result. The production fraction of Ξ_b^0 given by PYTHIA is $b_{\Xi^0} = 5.5\ 10^{-3}$, where also Ξ_b^0 from electromagnetic decays of $\Xi_b^{0'}$ and Ξ_b^{0*} are taken into account. The branching ratio of the decay $\Xi_b^0 \to \Lambda^0\ J/\psi$ can be roughly estimated multiplying $br_{\Lambda_b^0}$ by the Cabbibo suppression factor $\sin(\theta_c)^2 = 0.22^2$: $br_{\Xi_b^0} = 1.1\ 10^{-3}$ (or $br_{\Xi_b^0} < 0.3\ 10^{-3}$) using UA1 (CDF) results. Thus the number of $\Lambda_b^0 \to \Lambda^0\ J/\psi$ processes can be expected to be ≈ 300 times larger than the number of $\Xi_b^0 \to \Lambda^0\ J/\psi$ ones.

Both channels $\Lambda^0\ J/\psi \to p\pi^-\mu^+\mu^-$ and $\Lambda^0\ J/\psi \to p\pi^- e^+e^-$ can be used for the analysis. However statistics (Table2) will be dominated by the former decay as the trigger can be satisfied by one of the two muons. In the case of $\Lambda^0\ J/\psi \to p\pi^- e^+e^-$ the trigger comes only from semileptonic decay $b \to \mu X$ of the associated b-hadron. The reconstruction efficiencies are calculated by demanding that the events satisfy the cuts listed bellow. The first set of cuts corresponds the requirements set by the trigger:

- For $\Lambda^0\ J/\psi \to p\pi^-\mu^+\mu^-$ decay one muon is required to satisfy the single muon trigger conditions: $p_\perp^\mu > 6GeV$ and $|\eta| < 1.6$. For the second muon the cuts $p_\perp^\mu > 3GeV, |\eta| < 2.5$ are applied, supposing that within these values muon can be identified

using the last segment of the hadron calorimeter by its minimum ionizing signature.

- For Λ^0 J/ψ $\rightarrow p\pi^- e^+ e^-$ decay both electrons are required to have $p_\perp^e > 1GeV$. The low threshold for electrons is possible, because of electron identification in the transition radiation tracker (TRT) [24]. The events are required to contain one muon with a $p_\perp^\mu > 6GeV$ and $|\eta| < 1.6$

The second set of cuts corresponds to 'offline' analysis cuts. The same cuts as for $B_d^0 \rightarrow J/\psi K^0$ reconstruction [18] can be used (the only exception is the mass requirement for Λ^0 candidate, see the last of the next cuts) :

- The two charged hadrons from Λ^0 decay are required to be within the tracking volume $|\eta| < 2.5$, and transverse momenta of both to be greater than $0.5GeV$.

- Λ^0 decay length in the transverse plane with respect to the beam axis was required to be greater than $1cm$ and less than $50cm$. The upper limit ensures that the charged tracks from Λ^0 decay start before the inner radius of TRT, and that there is a space point from the innermost layer of the outer silicon tracker. The lower limit reduces the combinatorial background from particles originating from the primary vertex.

- The distance of closest approach between the two muon (electron) candidates forming the J/ψ was required to be less than $320\mu m$ ($450\mu m$), giving an acceptance for signal of 0.94.

- The proper time of the Λ_b^0 decay, measured from the distance between the primary vertex and the production point of the J/ψ in the transverse plane and the reconstructed $p_\perp$ of Λ_b^0 , was required to be greater than $0.5ps$. This cut is used to reduce the combinatorial background, giving the acceptance for signal events 0.68.

- The reconstructed Λ^0 and J/ψ masses were required to be within two standart deviations of nominal values.

The results on expected Λ_b^0 and Ξ_b^0 statistics and the errors of their polarization measurement are summarized in Table2. For both channels the statistics of reconstructed events at the luminosity $10^4 pb^{-1}$ will be
790 000 (220 000) Λ_b^0 and 2600 (720) Ξ_b^0 , where the values are derived using UA1 (CDF) results.

For this statistics the maximal value of the statistical error on the polarization measurement, calculated from formulae (9) and (10), will be 0.005(0.01) for Λ_b^0 and 0.09(0.17) for Ξ_b^0 .

Conclusion

At LHC luminosity $10^4 pb^{-1}$ the beauty baryons Λ_b^0 and Ξ_b^0 polarizations can be measured with the help of angular distributions in the cascade decays $\Lambda^0\ J/\psi\ \to p\pi^-\mu^+\mu^-$ and $\Lambda^0\ J/\psi\ \to p\pi^- e^+ e^-$ with the statistical precision better than 0.010 for Λ_b^0 and 0.17 for Ξ_b^0 .

Appendix

The polarization transfered to Λ_b^0 , which was produced indirectly in strong Σ_b and Σ_b^* decays, depends on the ratio $\frac{\Delta}{\Gamma}$ of the mass difference Δ between Σ_b and Σ_b^* and the decay rate Γ of $\Sigma_b \to \Lambda_b^0\ \pi$ or $\Sigma_b^* \to \Lambda_b^0\ \pi$ [25]. We will consider the limit $\Delta >> \Gamma$ when the baryons Σ_b and Σ_b^* form two well separated resonances and their contributions to Λ_b^0 polarization can be added incoherently. In such a case the polarization transfer can be easily calculated in a model-independent way using the angular distributions in cascade decays [26]. Thus considering the cascade decay $\Sigma_b \to \Lambda_b^0\ \pi$ or $\Sigma_b^* \to \Lambda_b^0\ \pi$, $\Lambda_b^0\ \to \Lambda^0\ J/\psi$, we have

$$w(\Omega,\Omega_1) \sim 1 + \alpha_{\Lambda_b^0} P_{\Sigma_b} (\cos\theta\cos\theta_1 \pm \sin\theta\sin\theta_1\cos\phi_1) \qquad (13)$$

for Σ_b (Σ_b^*). Here Ω=(θ,ϕ) are the polar and the azimuthal angles of the Λ_b^0 momentum $\vec{p}_{\Lambda_b^0}$ in the $\Sigma_b(\Sigma_b^*)$ rest frame with z-axis parallel to the production normal: $\vec{n} = \frac{\vec{p}_{inc}\times\vec{p}_{\Sigma_b}}{|\vec{p}_{inc}\times\vec{p}_{\Sigma_b}|}$, where $\vec{p}_{inc}$ and $\vec{p}_{\Sigma_b}$ are momenta of incident particle and Σ_b in c.m. system. Ω_1=(θ_1,ϕ_1) are the polar and the azimuthal angles of Λ^0 in Λ_b^0 rest frame with the axes defined as $z_1 \uparrow\uparrow \vec{p}_{\Lambda_b^0}$, $y_1 \uparrow\uparrow \vec{n}\times\vec{p}_{\Lambda_b^0}$. After the transformation of $\Omega_1 \to \Omega_1^{'}$ of Λ^0 angles from the helicity frame x_1, y_1, z_1 to the canonical frame x, y, z with $z \uparrow\uparrow \vec{n}$ and the integration over $\cos\theta$ and $\phi_1^{'}$ we get the distribution of the cosine of the angle between the Λ^0 momentum vector (Λ_b^0 decay analyzer) and the $\Sigma_b or \Sigma_b^*$ production normal (which can be considered coinciding with the Λ_b^0 production normal due to a small energy release in the $\Sigma_b or \Sigma_b^*$ decays):

$$w(\cos\theta_1^{'}) \sim 1 \mp \frac{1}{3}\alpha_{\Lambda_b^0} P_{\Sigma_b}\cos\theta_1^{'} \qquad (14)$$

for Σ_b (Σ_b^*) decay. One can thus conclude that Λ_b^0 retains $\frac{-1}{3}(\frac{1}{3})$ of the Σ_b (Σ_b^*) polarization. The analogical analyses of electromagnetic decays $\Xi_b^{0'} \to \Xi_b^0\ \gamma$ or $\Xi_b^{0*} \to \Xi_b^0\ \gamma$ show that Ξ_b^0 retains $\frac{-1}{3}(\frac{1}{3})$ of the $\Xi_b^{0'}(\Xi_b^{0*})$ polarization.

References

[1] K.Heller, Proceedings of the VII-th Int.Symp. on High Energy Spin Physics,Protvino,1986vol.I,p.81.

[2] L.Pondrom, Phys.Rep. 122(19985) 57.

[3] B.Andersson et al., Phys.Lett. 85B(1979) 417.

[4] T.A.De Grand, H.I.Miettinen, Phys.Rev. D24(1981) 2419.

[5] B.V.Struminsky, Yad.Fiz.34(1981) 1954.

[6] R.Lednicky, Czech.J.Phys.B33(1983) 1177; Z.Phys.C26(1985) 531.

[7] P.M.Ho et al., Phys.Rev.Lett. 65 (1990) 1713.

[8] A.Morelos et al., FERMILAB-Pub-93/167-E.

[9] R.Lednicky, Yad.Fiz.43(1986)1275 (Sov.J.Nucl.Phys. 43(1986), 817).

[10] G.Kane, Y.P.Yao, Nucl.Phys.B137(1978) 313.

[11] J.Szwed, Phys.Lett.105B(1981) 403.

[12] W.G.D. Dharmaratna, Gary R. Goldstein, Phys.Rev.D41(1990)1731.

[13] B.V.Batyunya et al., Czech.J.Phys.B31(1981) 11.

[14] C.M.Troshin, H.E.Tyurin, Yad.Fiz.38(1983) 1065.

[15] A.V.Efremov, O.V.Teryaev, Phys.Lett.B150(1985) 383.

[16] A.N.Aleev et al., Yad.Fiz.43(1986) 619.

[17] P.Chauvatet et al., Phys.Lett. 199B(1987) 304.

[18] The ATLAS Collaboration, CERN/LHCC/93-53, Oct.1993.

[19] W.Hoffmann,DESY 93-026(1993).

[20] H.Albrecht et al., DESY 93-156(1993).

[21] A.H.Ball et al., J.Phys. G: Nucl. Part. Phys.18(1992) 1703.

[22] UA1 Collaboration, Phys.Lett. 273B(1991) 544.

[23] CDF Collaboration, Phys.Rev. D47(1993) R2639.

[24] I.Gavrilenko, ATLAS Internal Note INDET-NO-016,1992.

[25] A.F.Falk and M.E.Peskin, SLAC-PUB-6311,1993.

[26] R.Lednicky, DrSc Thesis, JINR-Dubna 1990, p.174 (in russian).

i	f_{1i}	f_{2i}	F_i
0	$a_+a_+^* + a_-a_-^* + b_+b_+^* + b_-b_-^*$	1	1
1	$a_+a_+^* - a_-a_-^* + b_+b_+^* - b_-b_-^*$	P_b	$\cos\theta$
2	$a_+a_+^* - a_-a_-^* - b_+b_+^* + b_-b_-^*$	α_Λ	$\cos\theta_1$
3	$a_+a_+^* + a_-a_-^* - b_+b_+^* - b_-b_-^*$	$P_b\alpha_\Lambda$	$\cos\theta\cos\theta_1$
4	$-a_+a_+^* - a_-a_-^* + \frac{1}{2}b_+b_+^* + \frac{1}{2}b_-b_-^*$	1	$d^2_{00}(\theta_2)$
5	$-a_+a_+^* + a_-a_-^* + \frac{1}{2}b_+b_+^* - \frac{1}{2}b_-b_-^*$	P_b	$d^2_{00}(\theta_2)\cos\theta$
6	$-a_+a_+^* + a_-a_-^* - \frac{1}{2}b_+b_+^* + \frac{1}{2}b_-b_-^*$	α_Λ	$d^2_{00}(\theta_2)\cos\theta_1$
7	$-a_+a_+^* - a_-a_-^* - \frac{1}{2}b_+b_+^* - \frac{1}{2}b_-b_-^*$	$P_b\alpha_\Lambda$	$d^2_{00}(\theta_2)\cos\theta\cos\theta_1$
8	$-3Re(a_+a_-^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2\cos\phi_1$
9	$3Im(a_+a_-^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2\sin\phi_1$
10	$-\frac{3}{2}Re(b_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2 cos(\phi_1+2\phi_2)$
11	$\frac{3}{2}Im(b_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2 sin(\phi_1+2\phi_2)$
12	$-\frac{3}{\sqrt{2}}Re(b_-a_+^* + a_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\cos\theta_1\sin\theta_2\cos\theta_2\cos\phi_2$
13	$\frac{3}{\sqrt{2}}Im(b_-a_+^* + a_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\cos\theta_1\sin\theta_2\cos\theta_2\sin\phi_2$
14	$-\frac{3}{\sqrt{2}}Re(b_-a_-^* + a_+b_+^*)$	$P_b\alpha_\Lambda$	$\cos\theta\sin\theta_1\sin\theta_2\cos\theta_2\cos(\phi_1+\phi_2)$
15	$\frac{3}{\sqrt{2}}Im(b_-a_-^* + a_+b_+^*)$	$P_b\alpha_\Lambda$	$\cos\theta\sin\theta_1\sin\theta_2\cos\theta_2\sin(\phi_1+\phi_2)$
16	$\frac{3}{\sqrt{2}}Re(a_-b_+^* - b_-a_+^*)$	P_b	$\sin\theta\sin\theta_2\cos\theta_2\cos\phi_2$
17	$-\frac{3}{\sqrt{2}}Im(a_-b_+^* - b_-a_+^*)$	P_b	$\sin\theta\sin\theta_2\cos\theta_2\sin\phi_2$
18	$\frac{3}{\sqrt{2}}Re(b_-a_-^* - a_+b_+^*)$	α_Λ	$\sin\theta_1\sin\theta_2\cos\theta_2\cos(\phi_1+\phi_2)$
19	$-\frac{3}{\sqrt{2}}Im(b_-a_-^* - a_+b_+^*)$	α_Λ	$\sin\theta_1\sin\theta_2\cos\theta_2\sin(\phi_1+\phi_2)$

Table 1: The coefficients f_{1i}, f_{2i} and angular functions F_i in distribution (4).

Parameter	Value for Λ_b^0	Value for Ξ_b^0	Comment
$L[cm^{-2}s^{-1}]$	10^{33}		
$t[s]$	10^7		
$b(b \to B_b)$	0.08	$5.5\ 10^{-3}$	
$br(B_b \to \Lambda^0\ J/\psi)$	$2.2\ 10^{-2}$ $(0.6\ 10^{-2})$	$1.1\ 10^{-3}$ $(0.3\ 10^{-3})$	
$J/\psi \to \mu^+\mu^-$	0.06	0.06	
$\Lambda^0\ \to p\pi^-$	0.64	0.64	
$br(b \to \mu X) br(B_b \to \Lambda^0\ J/\psi)$	$2.2\ 10^{-3}$ $(0.6\ 10^{-2})$	$1.1\ 10^{-4}$ $(0.3\ 10^{-3})$	
$J/\psi \to e^+e^-$	0.06	0.06	
$\Lambda^0\ \to p\pi^-$	0.64	0.64	
$\sigma(b\bar{b})$	$500\mu b$	$500\mu b$	
$N(\mu^+\mu^- p\pi^-)$ accepted	1535000 (426000)	5120 (1420)	$p_\perp^\mu > 6GeV, \|\eta\| < 1.6$ $p_\perp^\mu > 3GeV, \|\eta\| < 2.5$ $p_\perp^{\pi,p} > 0.5GeV, \|\eta\| < 2.5$
$N(\mu ee p\pi^-)$ accepted	223000 (62000)	740 (210)	$p_\perp^\mu > 6GeV, \|\eta\| < 1.6$ $p_\perp^{e^+,e^-} > 1GeV, \|\eta\| < 2.5$ $p_\perp^{p,\pi^-} > 0.5GeV, \|\eta\| < 2.5$
$N(\mu^+\mu^- p\pi^-)$ reconstructed	720000 (200000)	2400 (670)	
$N(\mu ee p\pi^-)$ reconstructed	65000 (18000)	220 (60)	
the maximum statistical error on the polarization measurement $\delta(P_b)$	0.005 (0.010)	0.09 (0.17)	

Table 2: Summary on beauty baryon measurement possibilities for LHC experiment ATLAS. The values in brackets correspond to the CDF result, while the analogical values without brackets to the UA1 result.

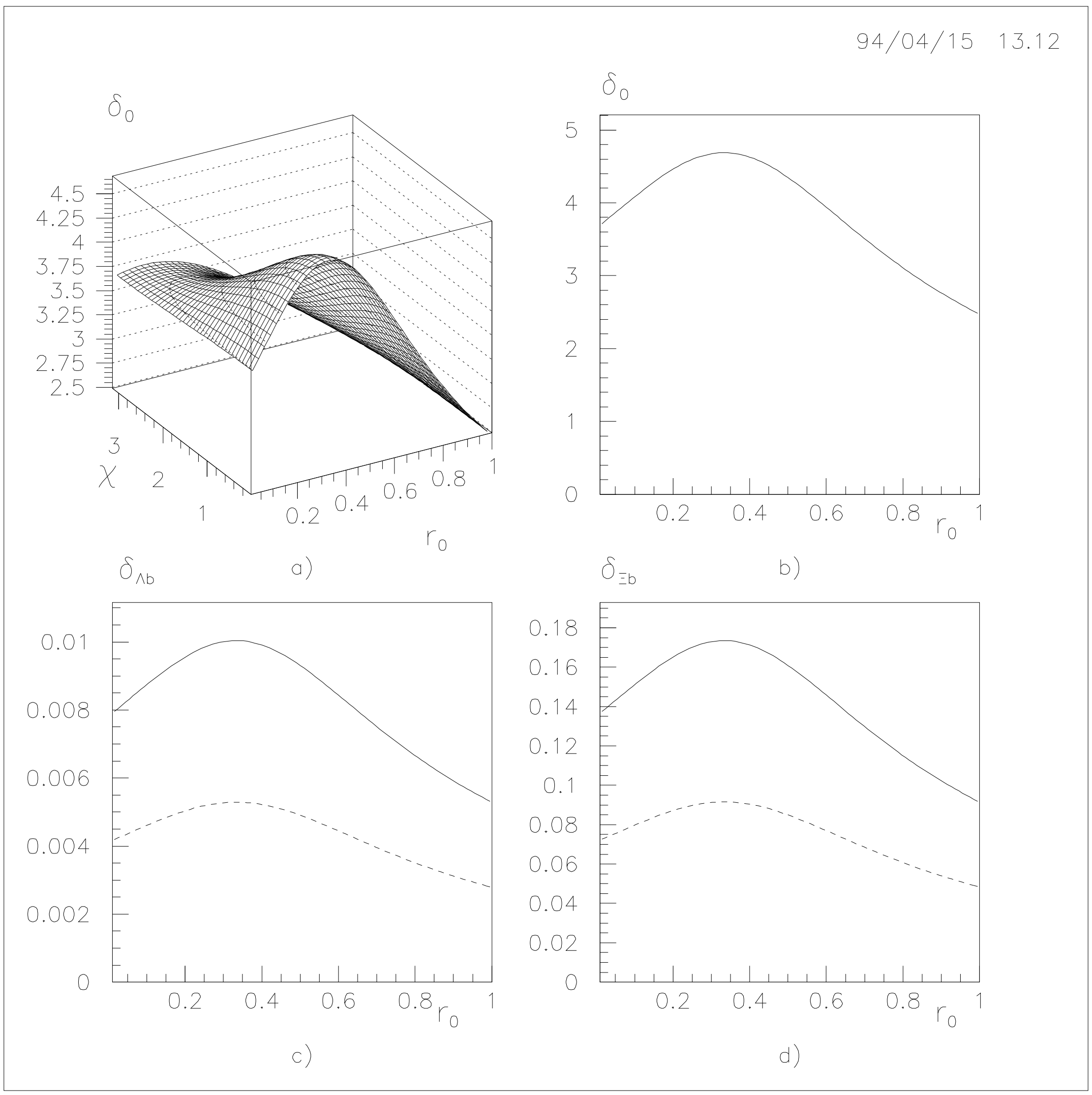

Figure 1: The maximal statistical error on the polarization measurement $\delta(P_b)$ and $\delta_0 = N^{+\frac{1}{2}}.\delta(P_b)$ defined in (10): δ_0 as a function of the relative contribution r_0 of the decay amplitudes with zero J/ψ helicity and of the relative phase χ of the amplitudes with J/ψ helicity equal to 0 and $\pm 1 (a)$. The $\chi = 0$ projection of this function (b) . Dependence of $\delta(P_b)$ on r_0 at $\chi = 0$ for Λ_b^0 expected on Atlas at LHC luminosity $10^4 pb^{-1}$ (c). Full (dotted) line corresponds to $\delta(P_b)$ derived from CDF (UA1) data. The same as (c) for Ξ_b^0 (d).

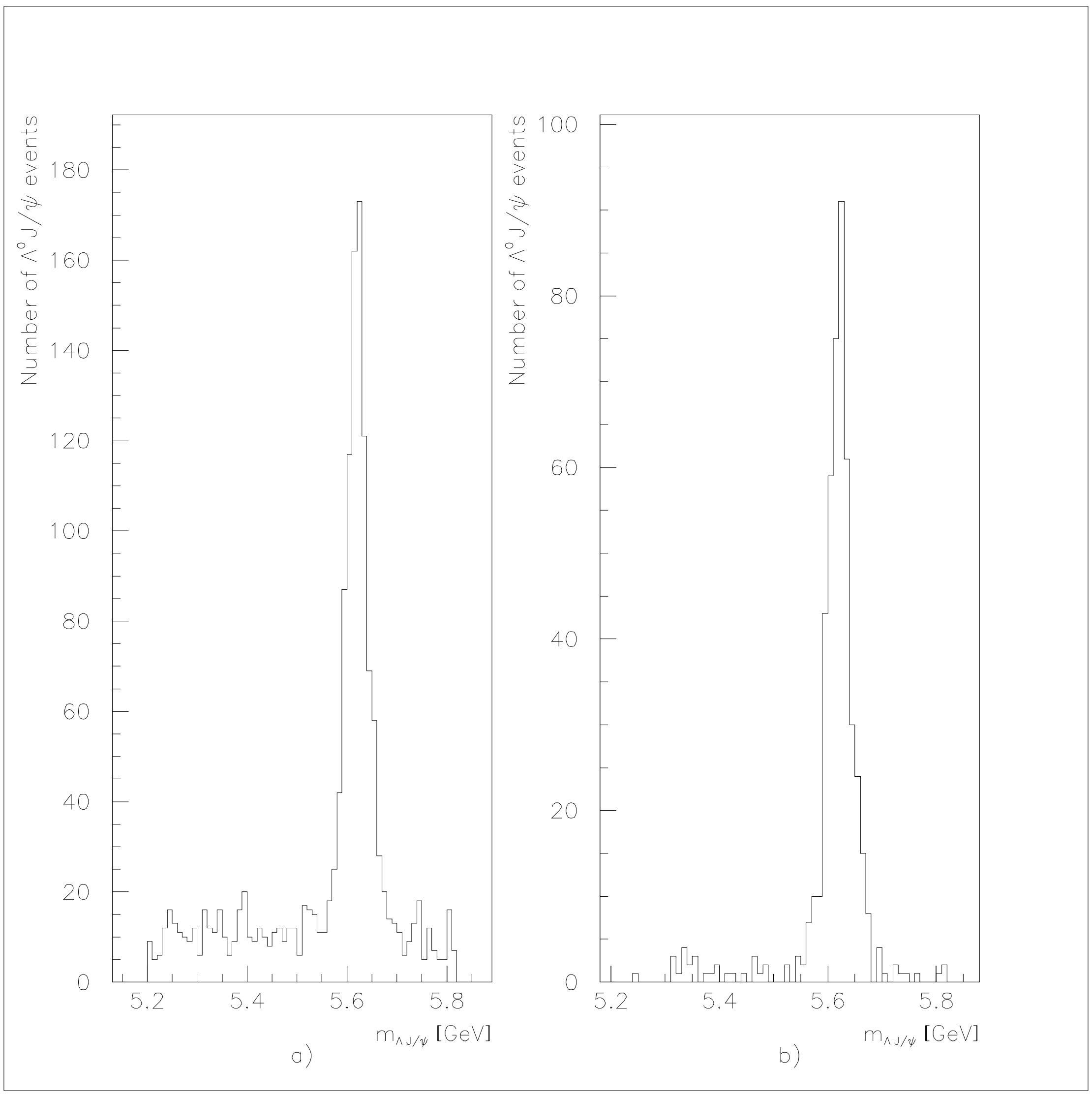

Figure 2: The Λ^0 J/ψ effective mass distribution. The peak at $5.62GeV$ is from Λ_b^0 and background comes from J/ψ from a b-hadron decay and Λ^0 either from the multiparticle production or from a b-hadron decay (a). The events that passed the cut on the transverse momenta ($p_T > 0.5GeV$) for p and π^- from Λ^0 decay (b).

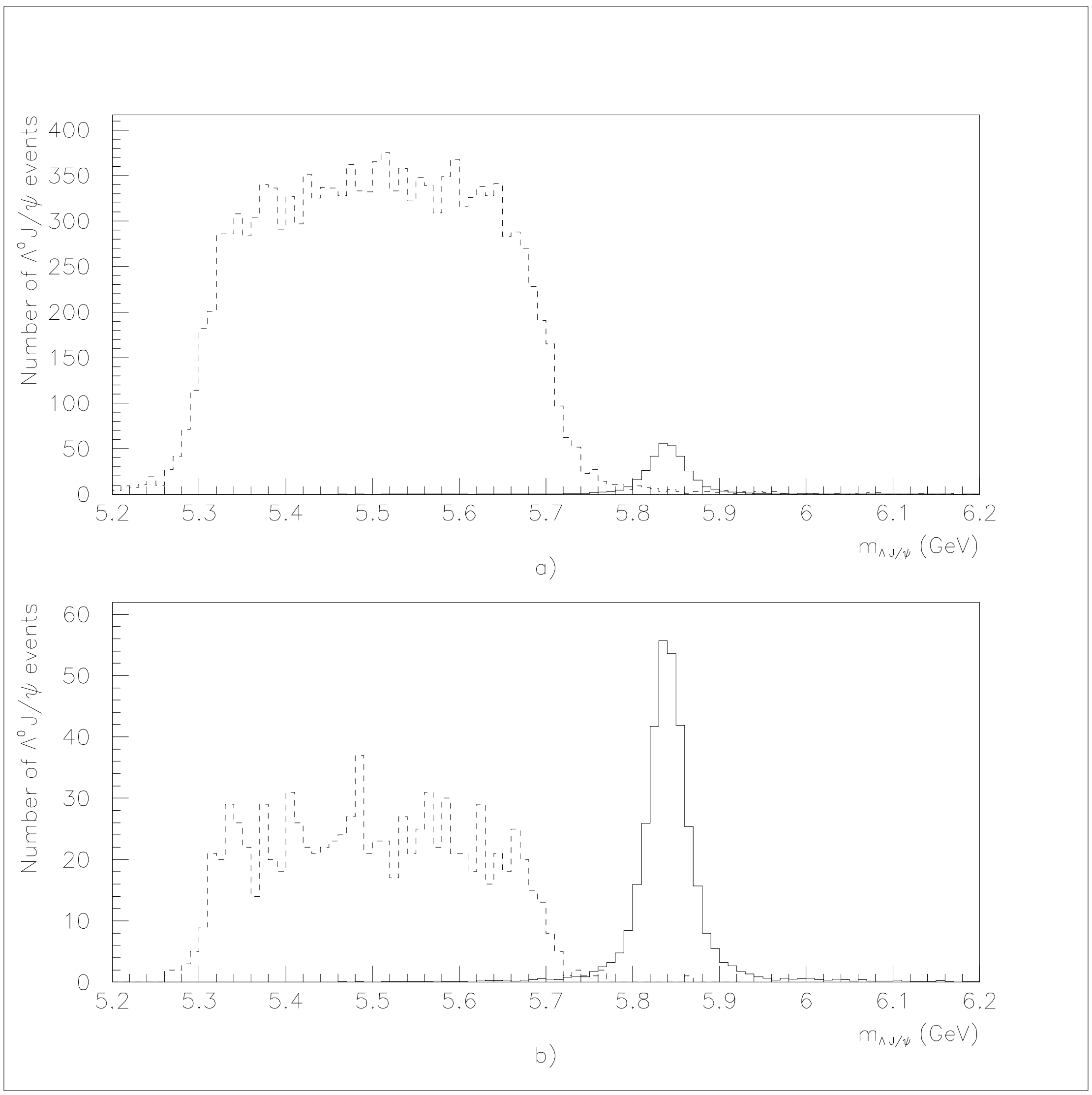

Figure 3: The $\Lambda^0\ J/\psi$ effective mass distribution: The peak at $5.84 GeV$ is from $\Xi_b^0 \rightarrow \Lambda^0\ J/\psi$ decay. The background with the centre at $\approx 5.5 GeV$ comes from $\Xi_b^0 \rightarrow \Xi^0 J/\psi$, $\Xi^0 \rightarrow \Lambda^0\ \pi^0$ and $\Xi_b^- \rightarrow \Xi^- J/\psi$,$\Xi^- \rightarrow \Lambda^0\ \pi^-$ decays (a). The events that passed the cut on the minimal distance of J/ψ and Λ^0 ($d < 1.5 mm$) (b).